EXPERIMENTAL STUDIES OF THE AIR QUALITY EVALUATION

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ABSTRACT

Three buildings are investigated to study the indoor air quality and the impact of the outdoor air pollution. These buildings, a swimming pool, a school and a nursery are located in an urban area. So, during experimental studies, typical outdoor and indoor pollutants such as carbon monoxyde, nitrogen dioxyde, carbon dioxyde, and total volatile organic compounds are monitored. Also, the relative humidity and the temperature are carried out. The analysis allows us to reveal several points. Except for CO_2 and punctually TVOC, the recorded indoor pollutant concentrations are very low in comparison with standard values, despite the symptoms and discomfort perceived by occupants.
Moreover, thanks to the attenuation phenomenon, outdoor pollution has an insignificant impact on the indoor air pollution. For these buildings, it seems that CO_2 or TVOC could be the best parameters to use for demand control ventilation system.

KEYWORDS
Carbon dioxyde, outdoor air, perceived air quality, public buildings, TVOC

INTRODUCTION

In order to have a better view of the parameters that could help for demand control ventilation system, an experimental study was carried out in three buildings : a swimming pool, a school and a nursery. These buildings are located in the city of Villeurbanne close to Lyon. To study indoor air quality and the impact of outdoor air pollution, continuous pollutant concentrations and physical parameters are measured. In the following, we briefly describe the experimental protocol and present the results and analysis of the first field experiment.

EXPERIMENTAL PROTOCOL

Each building is monitored continuously during one week (including occupancy and non occupancy periods) at two different periods (winter and spring or summer periods). Two different periods are chosen to see the variation of pollutant concentrations in accordance with outdoor pollution, people's habits. The parameters that were monitored are presented in table 1 together with measurement locations. In addition, the people's feeling about indoor comfort is collected. Only the measurements of the first period are reported here.

Table 1 : Parameters and devices used to measure the indoor environment

Measurement	Device	Time step	Measurement locations (and points number)		
			Swimming pool	School	Nursery
Continuous					
Temperature	Tinytag sensor	5 min	Around the pool (7) Outdoor next to air intake(1)	Classroom (6) Corridor (1) Outdoor (1)	Changing room (2) Bedrooms (2) Playroom (1) Hall (1) Outdoor (1)
Relative humidity	Tinytag sensor	5 min	Around the pool (3)	Classroom (2) Corridor (1)	Changing room (1) Bedroom (1) Playroom (1)
CO	Bruel & Kjaer Multi-gas 1302	15 min	Around the pool (5) Outdoor (1)	Classroom (4) Corridor (1) Outdoor (1)	Changing room (2) Bedrooms (2) Playroom (1) Outdoor (1)
CO_2	B & K 1302	15 min	Idem CO	Idem CO	Idem CO
TVOC[1]	B & K 1302	15 min	Idem CO	Idem CO	Idem CO
NO_2	Environment S.A.	1 hour	Right bottom (1)	Classroom (1) Outdoor (1)	Changing room (1)
Spot					
Air + water chloramines	Colorimetric method		Right bottom (1)		
Noise			Around the pool	Classroom (1)	Playroom (1)
Lighting			Around the pool Above pool (9)	Classroom (on the tables and the blackboard)	Changing room (3) Playroom (3)
Ventilation rate[2]	B & K 1302 - 1303		2800 m^3/h (according to recommendation)	110 m^3/h (against 390m^3/h recommended)	

[1] reference methane
[2] use of the concentration decay method

The nursery

The nursery is located in a residential district. It was built in 1980. Opening days are from Monday to Friday (7:30 - 18:30). During monitored week, it was occupied by about ten children and four adults. The ventilation system is a mechanical air exhaust system in the changing-room and the bedrooms. However, during our experiments, the ventilation system was not operating.

The swimming pool

Built in 1930, it is located in the underground of the National popular Theater, without daylighting openings. The swimming pool is opened 7 days a week between 8:30 and 21:00. The ventilation system is a mechanical air supply and exhaust system with heat recovery system.

The school

The primary school is located close to a heavy traffic street. It was built in 1930. All classrooms are naturally ventilated. The monitored classroom is occupied by 25 children (8-9 years) and one adult during four days per week from 8:30 - 11:30 and 13:30 - 16:30.

RESULTS

For these buildings, the indoor pollutant concentrations are compared with two standard values as defined in France : LRV (Low Risk Value) and HRV (High Risk Value) [1]. The chosen exposure time is equal to one hour. Indeed, for each studied building, the occupants stay for a minimum one hour duration. Moreover, outdoor and/or indoor parameters levels are compared. In tables 2, 3 and 4, shaded cells highlights parameters which levels are very high and/or are out of recommendations.

Table 2 : Indoor and outdoor parameters in the swimming pool (Thursday 4 to Thursday 11 June 98)

Parameter	Outdoor			Indoor			Indoor recommendation
	Min.	Max.	Mean	Min.	Max.	Mean	
Temperature (°C)	17.7	27.7	22.2	26.3	28.4	27.4	air T° = water T° + (1-2°C) = (30-34°C) [2]
Humidity (%)				61	81	72	60 to 70 % [2]
CO (ppm)	0	2.56	0.6	0.57	2.82	1.48	LRV = 26 ppm HRV = 67 ppm
CO_2 (ppm)	382	507	412	434	1353	627	LRV = 2500 ppm HRV = 6670 ppm
TVOC (ppm)	2.26	5.85	3.75	4.08	8.65	6.08	No standard values
NO_2 (ppb)				9	38	21	LRV = 213 ppb HRV = 532 ppb
Noise (dB(A))[1]						72	No standard values

[1]: mean value during period time of 90 minutes

Table 3 : Indoor and outdoor parameters in the school (Thursday 26 to Tuesday 31 March 98)

Parameter	Outdoor			Indoor			Indoor recommendation
	Min.	Max.	Mean	Min.	Max.	Mean	
Temperature (°C)	5.4	24.8	15.2	22	27	24	19 < T° < 26 °C (AICVF) [2]
Humidity (%)				14	31	22	30 < RH < 70 % [2]
CO (ppm)	0.06	3.18	0.72	0.05	3.14	0.85	LRV = 26 ppm HRV = 67 ppm
CO_2 (ppm)	391	523	431	394	1639	675	LRV = 2500 ppm HRV = 6670 ppm Limit comfort = 1000 ppm (WHO)
TVOC (ppm)	1.6	5.3	2.4	2	10.7	3	No standard values
NO_2 (ppb)	13	71	39	7	54	29	LRV = 213 ppb HRV = 532 ppb
Noise (dB(A))[1]						68-70	No standard values (comfort value : 55 dB(A))

[1]: mean value during time period of 90 minutes

Table 4 : Indoor and outdoor parameters in the nursery (Thursday 2 to Thursday 9 April 98)

Parameter	Outdoor			Indoor			Indoor recommendation
	Min.	Max.	Mean	Min.	Max.	Mean	
Temperature (°C)	7	23	13	21	23	22	19 < T° < 26 °C (AICVF) [2]
Humidity (%)				26	43	31	30 < RH < 70 % (AICVF) [2]
CO (ppm)	0.04	1.6	0.41	0.04	1.27	0.41	LRV = 26 ppm HRV = 67 ppm
CO_2 (ppm)	394	468	414	407	Playroom = 1455	Playroom = 643	LRV = 2500 ppm HRV = 6670 ppm
TVOC (ppm)	1.98	4.1	2.43	2.5	Playroom = 17.14	4.6	No standard values
NO_2 (ppb)				4	35	19	LRV = 213 ppb HRV = 532 ppb
Noise(dB(A))[1]						72	No standard values (comfort value : 55 dB(A))

[1]: mean value during period time of 90 minutes

DISCUSSION

Air quality

In comparison with LRV, indoor pollutant concentrations are very low (tables 2 to 4).
In the swimming pool, people's complaints are about lethargy (10 by 15 people), irritated eyes (9 by 15 people), breathing difficulties (7 by 15 people). There seems to be no correlation between the indoor pollutant levels and the symptoms perceived by the occupants on the basis of the LRV knowledge. Because no TVOC standard values exist, it is difficult to conclude a

relationship between symptoms, discomfort and TVOC level. Moreover, spot measurements of air chloramines level (between 58 and 96 $\mu g/m^3$) are lower than the indoor recommendation (= 500 $\mu g/m^3$) [3, 4], but do not allow to know the effect of a long exposure time. From the monitoring, temperature and relative humidity are never in agreement with the indoor recommendation and could be responsible for people's discomfort (lethargy and breathing difficulties symptoms).

In the school, indoor pollutants concentrations and relative humidity are low, except the CO_2 at some times. For the studied classroom, it appears that noise (about 70 dB(A) during 90 minutes) is the major problem.

People complaints are about dry skin and irritation problems. Maybe, there is a correlation between these symptoms, the low relative humidity and the important TVOC level (mainly in the changing room and playroom when cleaning time). Moreover, because the ventilation system is not operating, an accumulation phenomenon appears (fig.1). In comparison with weekends, indoor concentrations are higher than outdoor concentrations and do not come down with the outdoor level at night time.

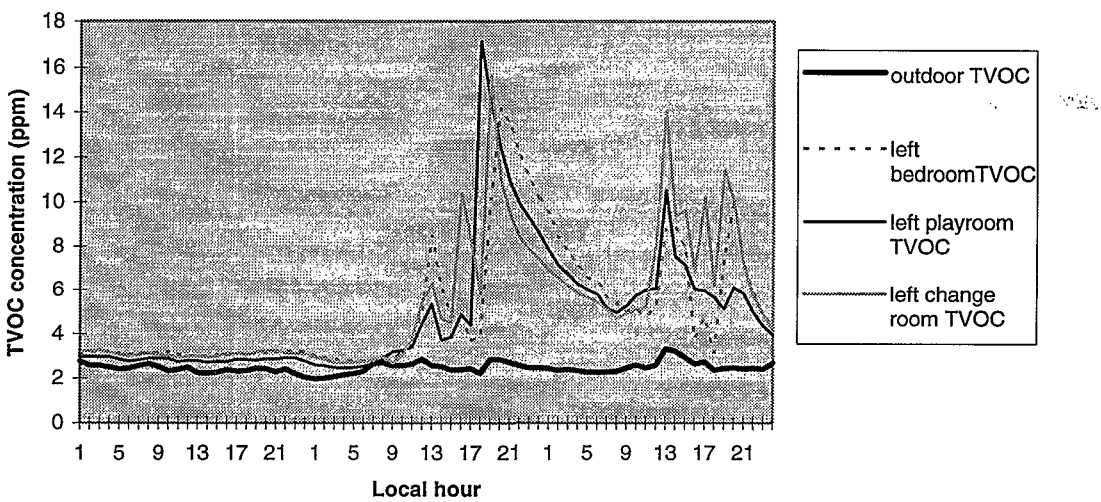

Figure 1 : indoor and outdoor TVOC concentrations
(nursery - from Sunday 5 to Tuesday 7 April 98)

The prevalence of the indoor air pollutants and consequently the demand control ventilation system seems to vary according to the building type. The second field experiment will allow to confirm or not the results of the discussion.

Relationships between indoor and outdoor pollutants

Our three buildings are not well ventilated. The school is naturally ventilated by opening the windows and two others are mechanically ventilated but had to face maintenance problems. No indoor CO and NO_2 sources have been identified in our buildings. These indoor pollutant concentrations result from outdoor, especially from the traffic. An outdoor maximum concentration involves an indoor maximum concentration (fig.2). In the three buildings, a correlation factor between CO indoor and outdoor exist : 0.76 (swimming pool), 0.7 (nursery) and 0.9 (school). We can observe also an attenuation effect between outdoor and indoor peaks (fig.2). The reduction factor varies with buildings, locations, date and can reach 40 %. So, this phenomenon limits the importance of outdoor pollution influence on indoor environment.

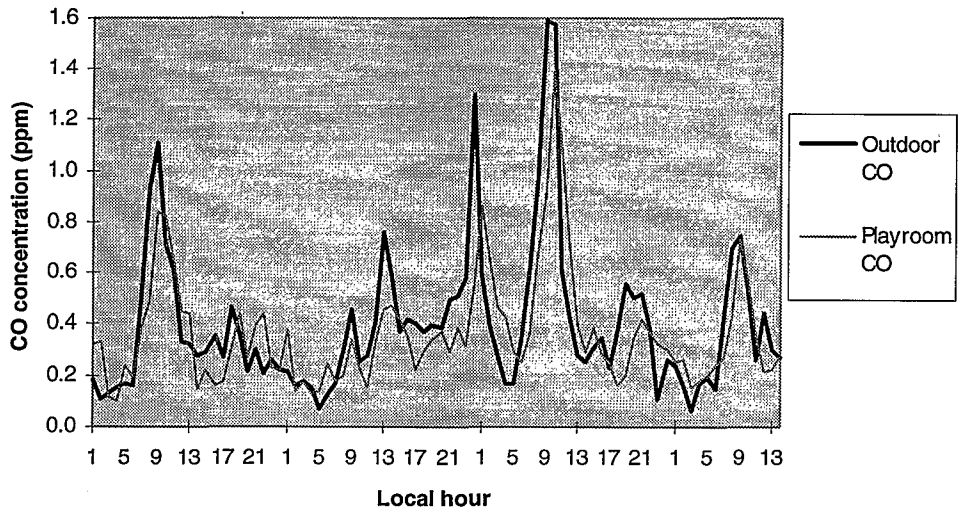

Figure 2 : relationship between indoor and outdoor CO concentrations (nursery - from Monday 6 to Thursday 9 April 98)

CONCLUSION

For our specific buildings, the most important pollutants to consider were pollutants produced inside the building as CO_2 and TVOC. Although TVOC limit concentration are not well defined at this time, it could be one criteria of the indoor air quality problem for some public buildings. Previous results has showed us a significant attenuation of the outdoor pollutants while indoor concentration can reveal an accumulation phenomenon of the indoor pollution depending on the ventilation rate. The indoor relative humidity is an important parameter too. But, as it depends also on outdoor factors, it will be necessary to take these two parameters into account for the ventilation system control.
The winter monitoring began on January 99. It will allow a comparison between the two different periods. The next step of this work will be to investigate the multi-criteria problem of indoor air quality so as to control in an efficient way the parameters of ventilation systems.

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